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NPG Report No. 1279

IGNITION OF LIQUID PROPELLANT IN THE 40MM GUN

U. S. NAVAL PROVING GROUND
DAHLGREN, VIRGINIA

Copy No. 35

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Date : 15 June 1954

CONTENTS

ABSTRACT

The tests reported here were conducted to determine the effects produced on the ballistics of a liquid monopropellant round by advancing the point of venting of the primer within the propellant column. The tests were conducted with two case configurations in which the L/D ratios of the propellant columns were approximately 3.4 and 5.0. As the point of venting was advanced, muzzle velocity increased in rounds with the L/D ratio of 5.0, but decreased in those with the L/D ratio of 3.4. The amount of unburned propellant remaining in the case after firing increased in both case configurations. In both configurations, the pressure curves were transformed from curves with two distinct pressure peaks, through stages approximating plateau configurations, to curves with one well defined pressure maximum.

FOREWORD

This is the Second Partial Report on Task Assignment NPG-Re5a-39-1-53, "Liquid Propellant Guns". Reference (a) established the task and authorized the use of funds under this task for the development of a liquid propellant round and the study of erosion characteristics of liquid propellants in guns. This is also the Second Partial Report on Task Assignment NPG-Re2d-12-1-53, "Liquid Propellant for Guns; test and evaluation of". The object of this task, established by reference (b), was to develop a prepackaged hydrazine monopropellant round and test its performance in automatic fire. Since both objectives require the development of a satisfactory round before either rapid fire or erosion tests can be conducted, the objectives of the two task assignments are combined in these tests. The experimental work described in this report was accomplished between 18 August 1953 and 14 September 1953.

This report was reviewed by:

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INTRODUCTION

As a result of the research reported in reference (c) a hydrazine monopropellant round was developed by which service velocity in the 40mm gun could be exceeded by as much as 150 f/s without exceeding the chamber pressure of the solid propellant service charge for this gun. However, one characteristic of this round was the development of two pressure peaks with the second peak often equalling the first in magnitude. It was observed that the occurrence of this second maximum was frequently associated with more or less severe damage to the mouth of the case. The tests reported here were undertaken to determine if and to what extent the ballistics of the above round might be improved by relocating the point at which the primer vented in the propellant column. In particular, it was of interest to reduce the magnitude of the second pressure peak.

DESCRIPTION OF MATERIAL

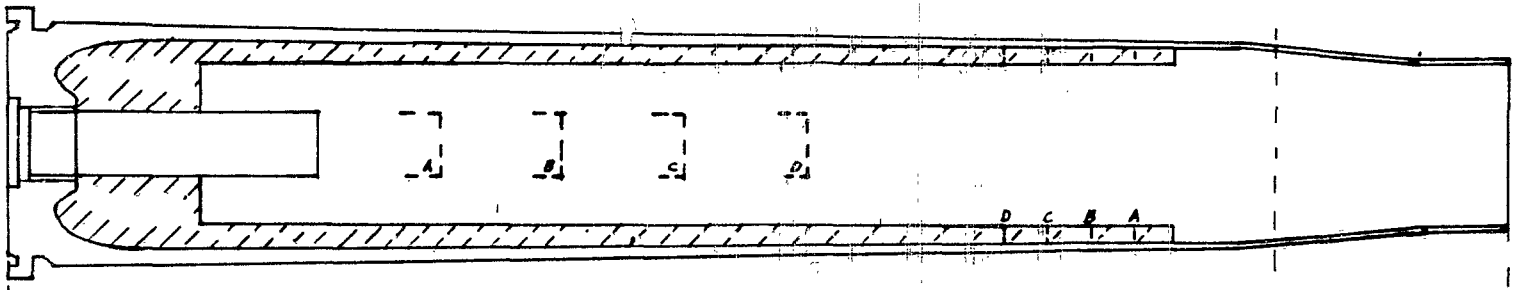
All the rounds used in these tests were loaded with 310 grams of hydrazine monopropellant of the following composition:

Hydrazine	73.5%
Hydrazine Nitrate	22.6%
Water	3.9%

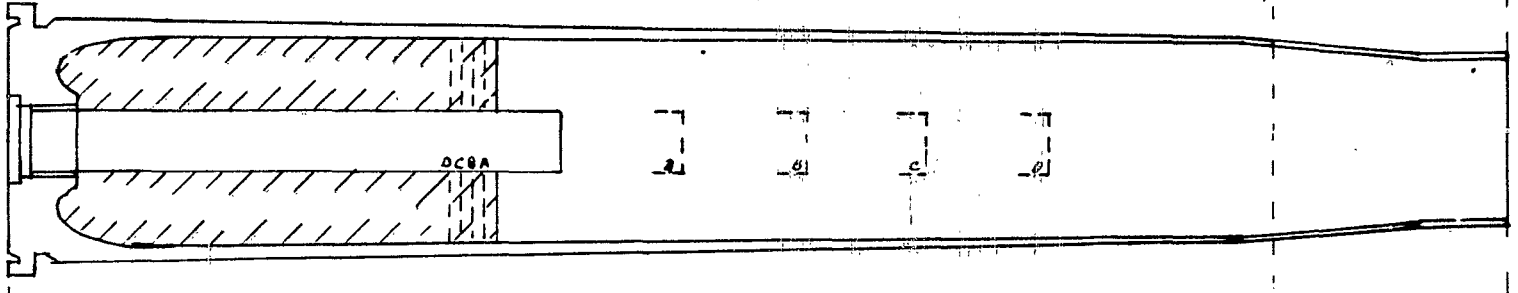
The two case assemblies, designated C-4 and C-5, produced L/D ratios of the propellant columns of approximately 5.0 and 3.4, respectively. A free volume of 1% was provided in the C-4 assembly and 5% in the C-5. The excess case volume was occupied by a paraffin beeswax mixture. This wax was distributed in the cases as shown in Figure 1 in which the wax is the hatched areas.

Cases were 40mm Mk 2 modified to receive Mk 42 primers.

ASSEMBLY C-4



ASSEMBLY C-5



Projectile Base

FIGURE NO. 1

SKETCH OF CASE ASSEMBLIES

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Primer tubes were cylindrical brass tubes with I.D.'s of 7/16 in. and 0.025 thick burst diaphragms at the ends of the tubes. The tubes were loaded with 0.2 grams of ammonium perchlorate and 36 grains of FFFG black powder. Lengths of tubes are shown in Figure 1 and tabulated in Tables 1 and 2.

Standard 40mm Mk 2 projectiles were used in all rounds.

DESCRIPTION OF TEST EQUIPMENT

The firings were conducted in a 40mm Mk A Mod 1 barrel mounted in a 6 pounder mount Mk 7 Mod 1. The barrel and the mount were modified to receive dynamic pressure gauges in the chamber 3.0 and 10.0 from the breech face. The instrumentation, including pressure gauges, used on these tests was described in reference (c).

PROCEDURE

The method of preparing and mixing the propellant was similar to that used in reference (c) except that temperatures up to 102°C and three or four days evacuation with the vacuum pump were required to expel water during the preparation of hydrazine nitrate. The adjustment of the case volume was also the same except that the filler was distributed in the case before the projectile was fitted and crimped.

The first series of firings comprised the rounds with the C-4 assembly. These were fired with primer extension tubes increasing in length from 3" to 6" by one inch increments. The volume occupied by the wax filler was reduced on succeeding rounds by the amount of increase in volume of the primer tubes as shown in Figure 1. Pressures were recorded in the gun chamber at 3" and 10" from the breech face.

The second series of firings comprised rounds with the C-5 assembly. A group of rounds with primer tubes 4" to 8" long were fired following the same procedure as above. A second group with tubes 4" to 7" in length was then fired as a reproducibility check.

RESULTS AND DISCUSSION

The effects produced by advancing the position of venting of the primer within the propellant column with the two different case assemblies may be seen by comparing the pressure time records reproduced in Figures 2 through 7, and by comparing the values for maximum pressure and muzzle velocities tabulated in Tables 1 and 2. The ejection times tabulated in the tables are the times from the occurrence of the first pressure spike to ejection of the projectile.

The C-4 Assembly

It is noted that, in general, the second pressure peak diminished as compared to the first pressure peak as the point of primer venting was moved forward in this assembly. The end of the tube was torn off on firing round 1 with the 3" primer, possibly because of the high secondary pressure registered by the 10"0 gauge. On the other hand, round 4 with the longest primer showed no secondary peak pressure on the oscillogram record. Velocities increased slightly with increased primer length except for round 3 which gave a value only slightly lower than the preceding round. The velocity increased from 2568 to 2675 f/s for the series. The velocities are somewhat lower than expected throughout the group even though freshly prepared propellant was used, but the primer length effects are, nevertheless, comparable.

TABLE 1 BALLISTIC DATA FROM C-4 ASSEMBLY

Rd. No.	Primer Length	Ejection Time (ms)	Pressure (psi) First Peak 3"0 Gauge	First Peak 10"0 Gauge	Second Peak 3"0 Gauge	Second Peak 10"0 Gauge	Velocity (f/s)
1	3"0	5.0	33060	32600	38100	41000	2568
2	4"0	4.7	36900	38100	31900	33850	2606
3	5"0	4.2	41650	39870	31175	32900	2594
4	6"0	4.0	51175	48850	---	---	2675

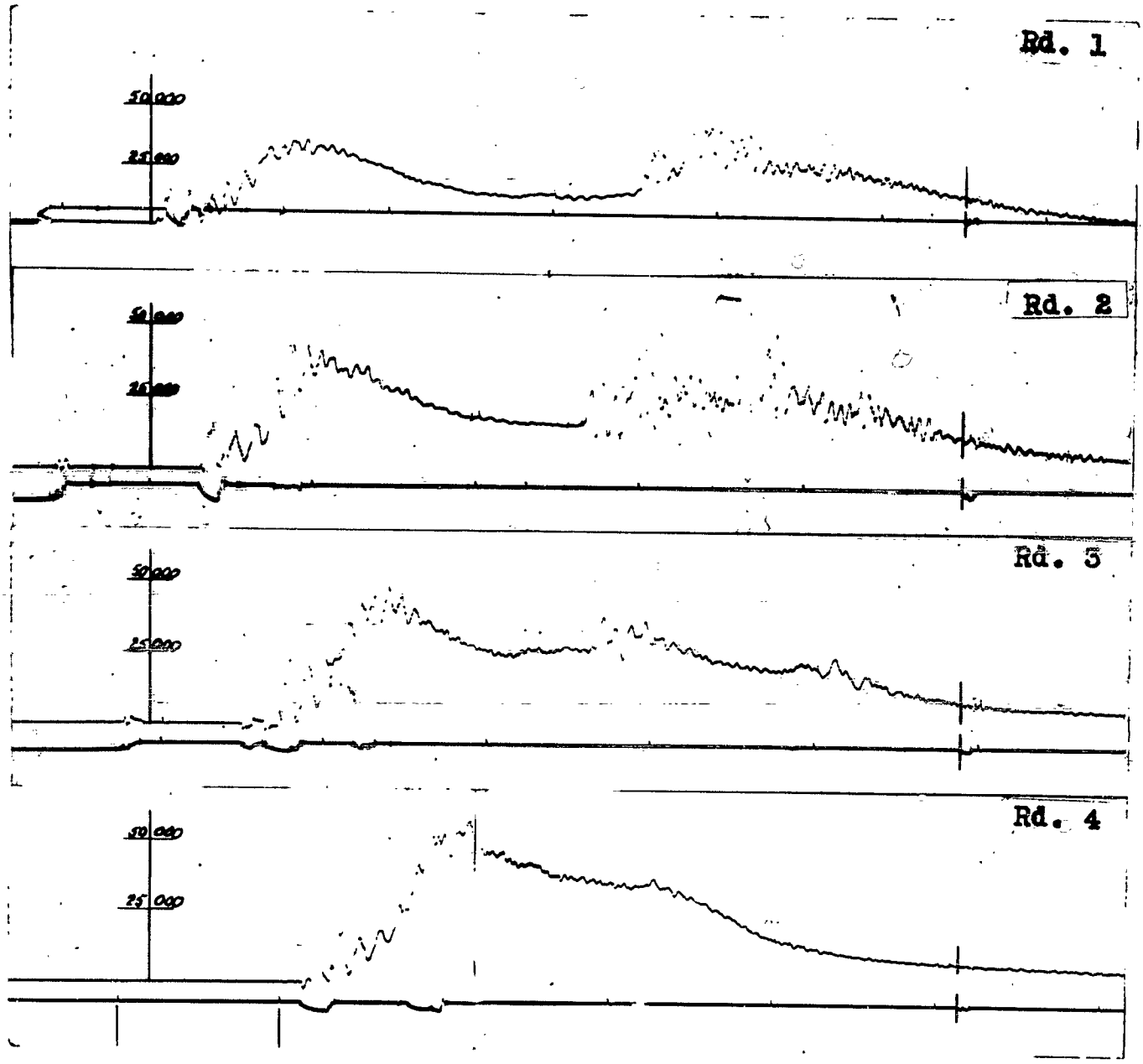

FIGURE NO. 2

PRESSURE-TIME OSCILLOGRAMS OBTAINED WITH ASSEMBLY C-4
AT THE 3" GAGE POSITION

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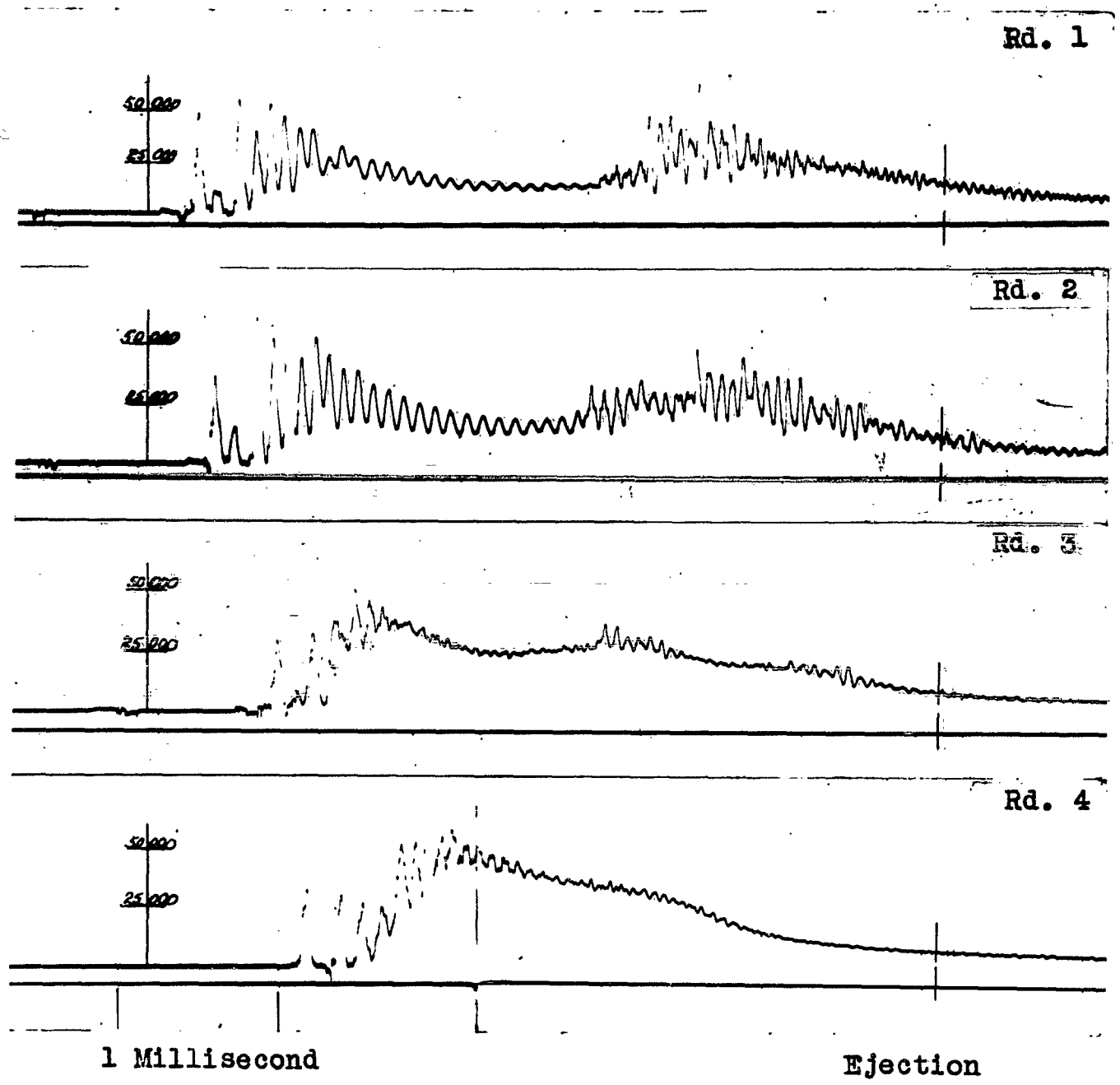

FIGURE NO. 3

PRESSURE-TIME OSCILLOGRAMS OBTAINED WITH CASE ASSEMBLY C-4
AT THE 10" GAGE POSITION

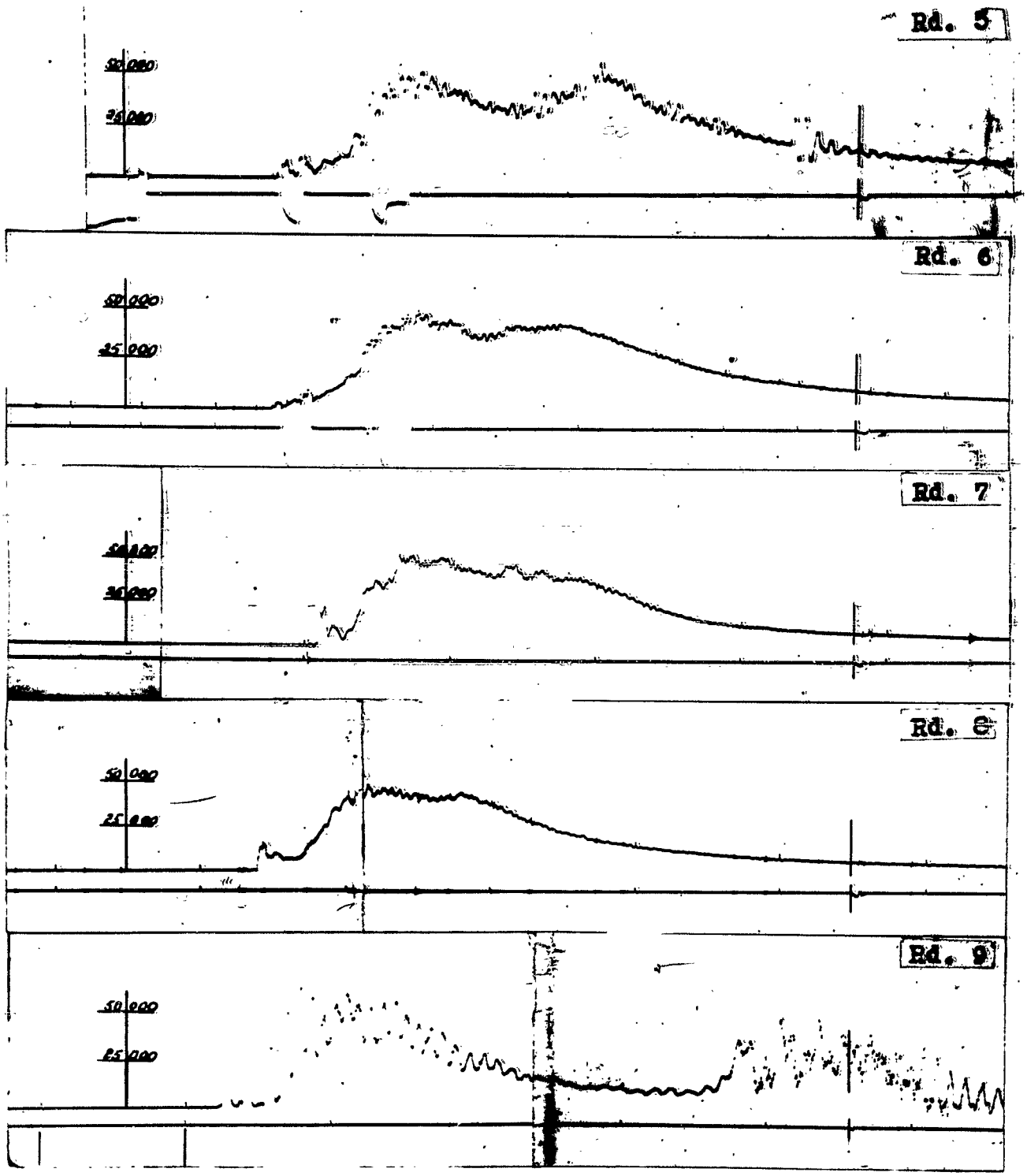

FIGURE NO. 4

PRESSURE-TIME OSCILLOGRAMS OBTAINED WITH CASE ASSEMBLY C-5 AT THE 3" GAGE POSITION

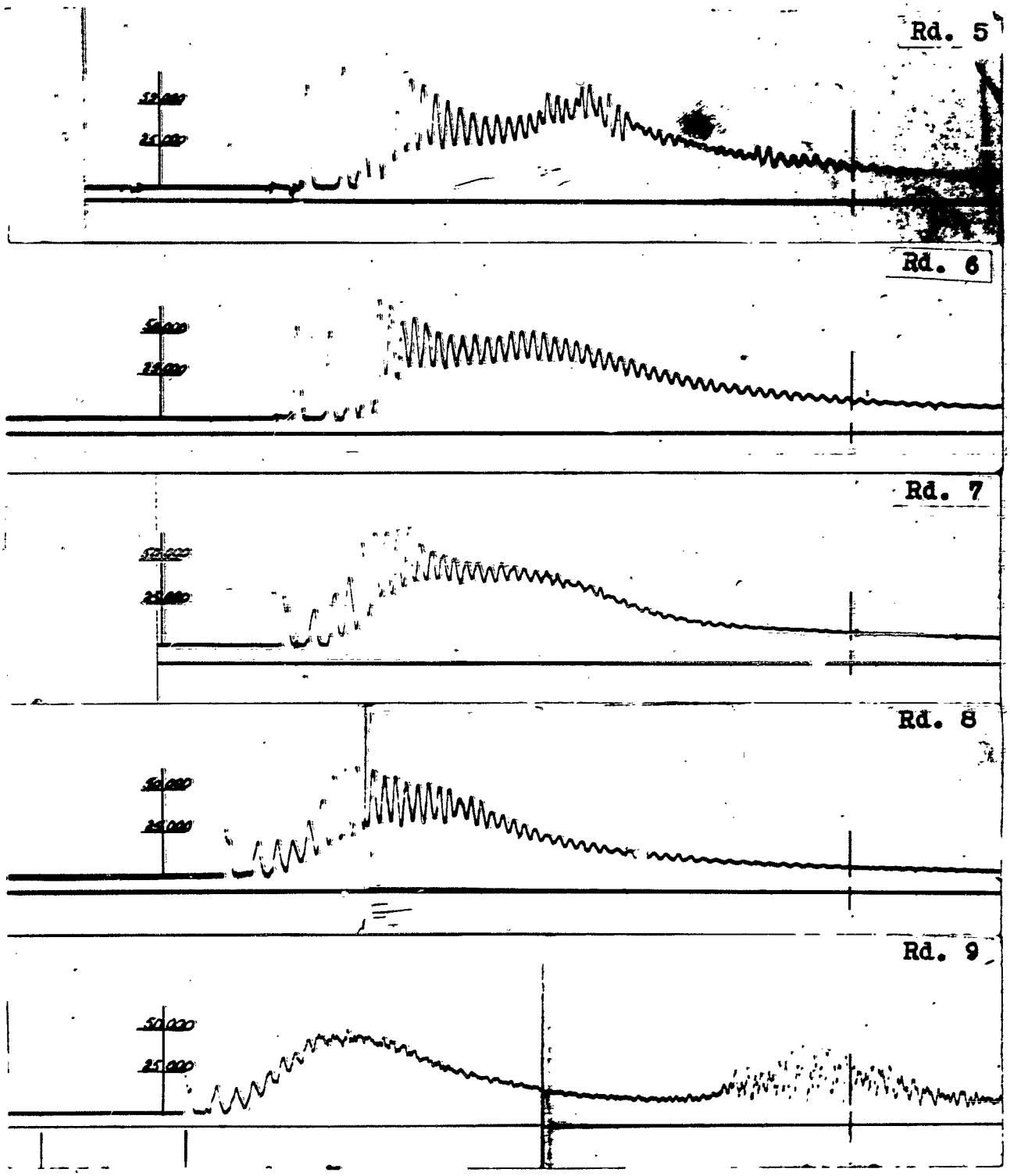

FIGURE NO. 5

PRESSURE-TIME OSCILLOGRAMS OBTAINED WITH CASE ASSEMBLY C-5 AT THE 10" GAGE POSITION

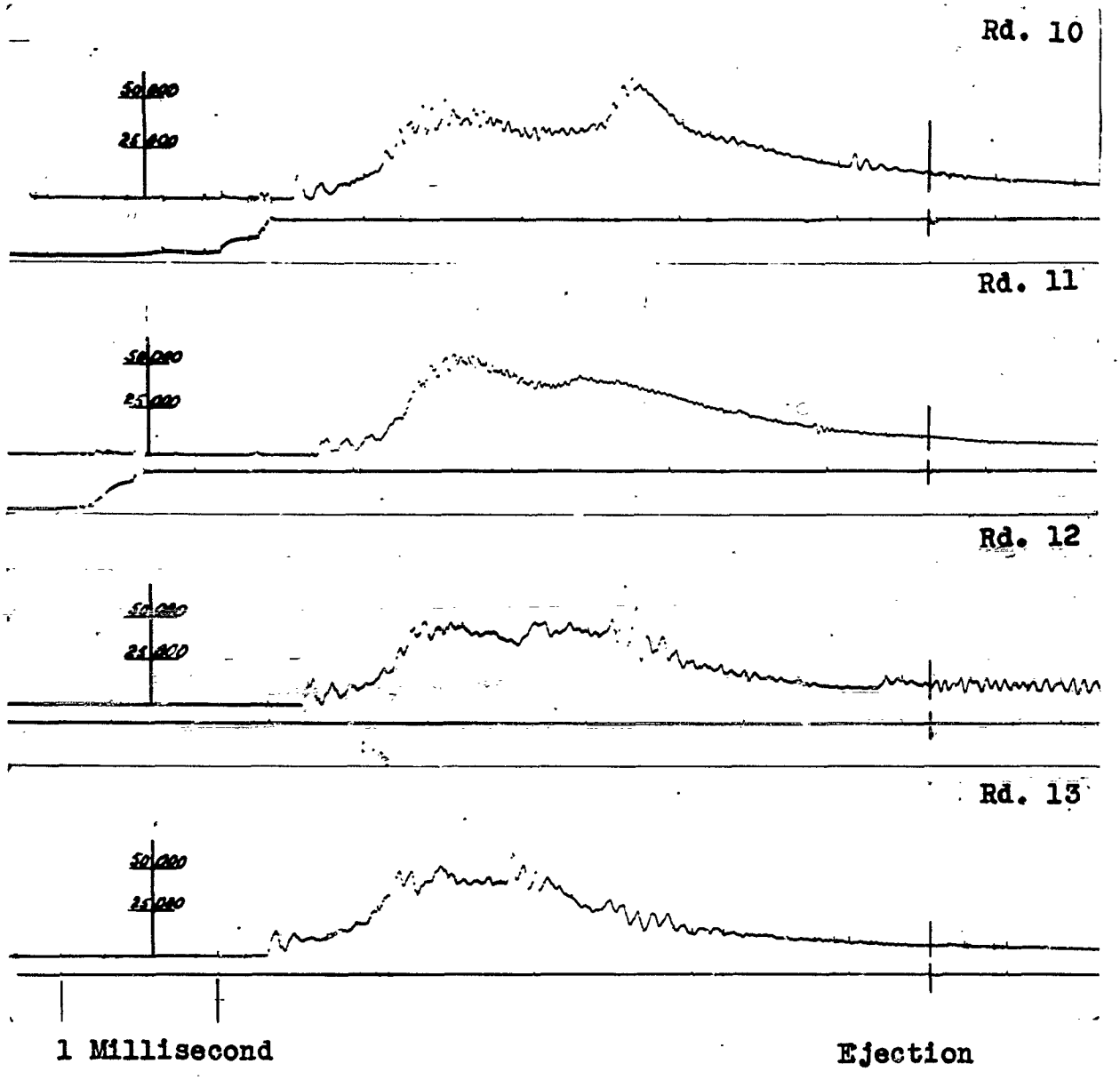

FIGURE NO. 6

PRESSURE-TIME OSCILLOGRAMS OBTAINED WITH ASSEMBLY C-5
AT THE 3" GAGE POSITION

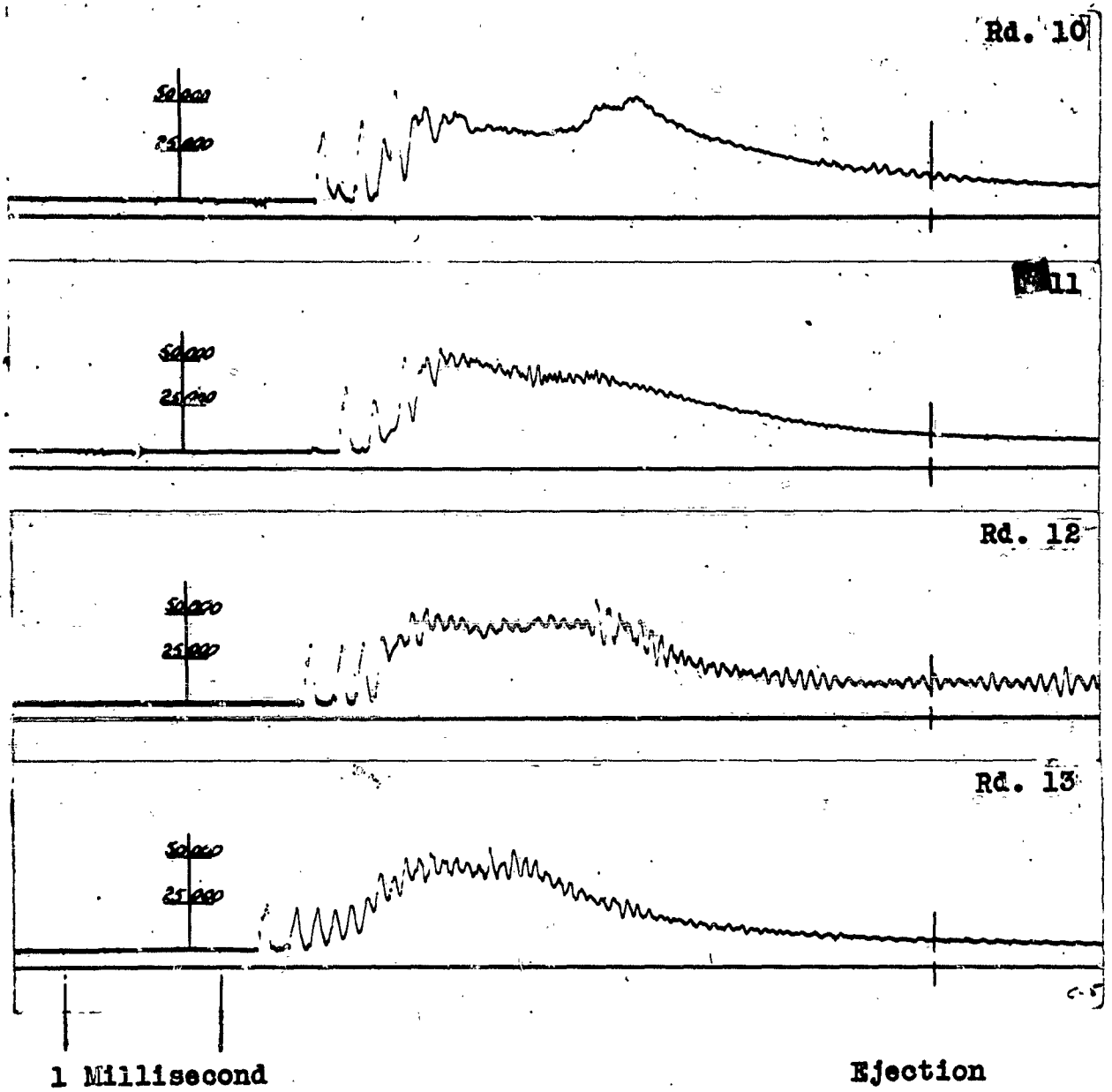

FIGURE NO. 7

PRESSURE-TIME OSCILLOGRAMS OBTAINED WITH ASSEMBLY C-5
AT THE 10" GAGE POSITION

The C-5 Assembly

The general tendency with the C-5 case assembly, as with the C-4, was for the second pressure peak to diminish in amplitude relative to the first as the point of venting was advanced in the propellant column. However, the drop in pressure between the two maxima is relatively much less in this series and close approximations to plateau conditions were obtained on rounds 6, 7, 11 and 12.

A marked decrease in muzzle velocity resulted in this series as the venting point of the primer was advanced in the case. From an average of 3020 f/s on the two rounds with 4"0 primers the velocity dropped to 2173 f/s on the round with the 8"0 primer.

TABLE 2 BALLISTIC DATA FROM C-5 ASSEMBLY

Rd. No.	Primer Length	Ejection Time (ms)	Pressure (psi) First Peak 3"0 Gauge	First Peak 10"0 Gauge	Second Peak 3"0 Gauge	Second Peak 10"0 Gauge	Velocity (f/s)
5	4"0	4.0	36850	34200	49100	39750	3038
6	5"0	4.0	46050	36900	41450	35050	2852
7	6"0	4.1	48600	52450	43050	---	2750
8	7"0	4.1	44600	40200	42250	---	2389
9	8"0	4.4	43500	30200	28100	16850	2173
10	4"0	4.0	43500	39600	54550	48685	3001
11	5"0	3.9	51100	51800	41650	42395	2867
12	6"0	4.0	42150	43300	45520	42550	2752
13	7"0	4.2	45200	47050	43300	46650	2484

General

In comparing the results from the two case assemblies, it is to be noted that the second pressure peak can be eliminated and an essentially plateau type pressure curve produced by proper location of the venting point of the primer in the propellant column. However, the amount of unburned propellant remaining in the case is increased as venting is advanced. This condition would be particularly undesirable under rapid fire conditions. In the C-5 assembly, advancing the point of venting results in a marked

reduction in the velocity obtained with this assembly. Thus, while advancing the point at which the primer vents in the propellant column improves the ballistics of the round in some respects, it has detrimental effects in others. The C-5 assembly with venting of the primer near the base of the propellant column is the most satisfactory of the rounds tested with respect to velocity obtained, shape of pressure curves, and amount of propellant utilized.

CONCLUSIONS

From the firings of these tests, it is concluded that advancing the point of venting of the primer within the propellant column produces the following effects:

a. Muzzle velocity is increased in rounds with a propellant column L/D ratio of 5.0, but is decreased in rounds with a ratio of 3.4.

b. The amount of unburned propellant remaining in the case after firing increases in both case configurations. Negligible amounts of propellant were observed in cases of either configuration in which the primers vented near the base of the propellant column.

c. In both case configurations, the pressure curves were transformed from curves with two distinct pressure peaks, through stages approximating plateau configurations, to curves with one well defined pressure maximum.

REFERENCES

(a) BUORD ltr NP9-Re5a-FWB:fl of 15 Jul 1952
(b) BUORD Conf ltr NP9-Re2d-WES:aph Ser 49271 of 17 Dec 1952
(c) NPG Conf Report No. 1200 of 13 Nov 1953

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Subject: Ignition of Liquid Propellant in the 40mm Gun
by G. L. Poudrier and K. H. Crutchfield, Armament Department, U. S. Naval Proving Ground, Dahlgren Virginia
15 June 1954

ABSTRACT

The tests reported here were conducted to determine the effects produced on the ballistics of a liquid monopropellant round by advancing the point of venting of the primer within the propellant column. The tests were conducted with two case configurations in which the L/D ratios of the propellant columns were approximately 3.4 and 5.0. As the point of venting was advanced, muzzle velocity increased in rounds with the L/D ratio of 5.0, but decreased in those with the L/D ratio of 3.4. The amount of unburned propellant remaining in the case after firing increased in both case configurations. In both configurations, the pressure curves were transformed from curves with two distinct pressure peaks, through stages approximating plateau configurations, to curves with one well defined pressure maximum.